GERB: Current status, validation and science results

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With many valuable contributions from other members of the GERB Project and the GERB International Science Team.

Outline

- GERB programme – current status
- GERB Edition 1 record:
  - data availability
  - data gaps
  - future releases
  - geolocation
- GERB – CERES comparisons
- Future studies & Edition 2

GERB Team

- Imperial College London
  John Harries – Principal Investigator
  Steve Kellock – Operations Manager
  Jacqui Russell – GERB Project Scientist
  Rich Bantges – GERB Deputy Project Scientist
  James Rufus – Operations Scientist
  Jon Murray – Calibration Scientist
- Other institutes
  Rutherford Appleton Laboratory (UK)
  Royal Meteorological Institute of Belgium
  University of Leicester (UK)
  EUMETSAT, ESA, NPL, NASA, others

GERB Programme

- GERB-2

  Launched on MSG-1 (MET-8) Dec 2002

  Operational from Feb 2004 – May 2007

  Currently in SAFE
- GERB-1

  Launched on MSG-2 (MET-9) Dec 2005

  Operational from Apr 2007 –
- GERB-3

  Launch planned for ~Jan 2011 on MSG-3

  Calibration check at Imperial Jan 2008

  Improved VISCS
- GERB-4

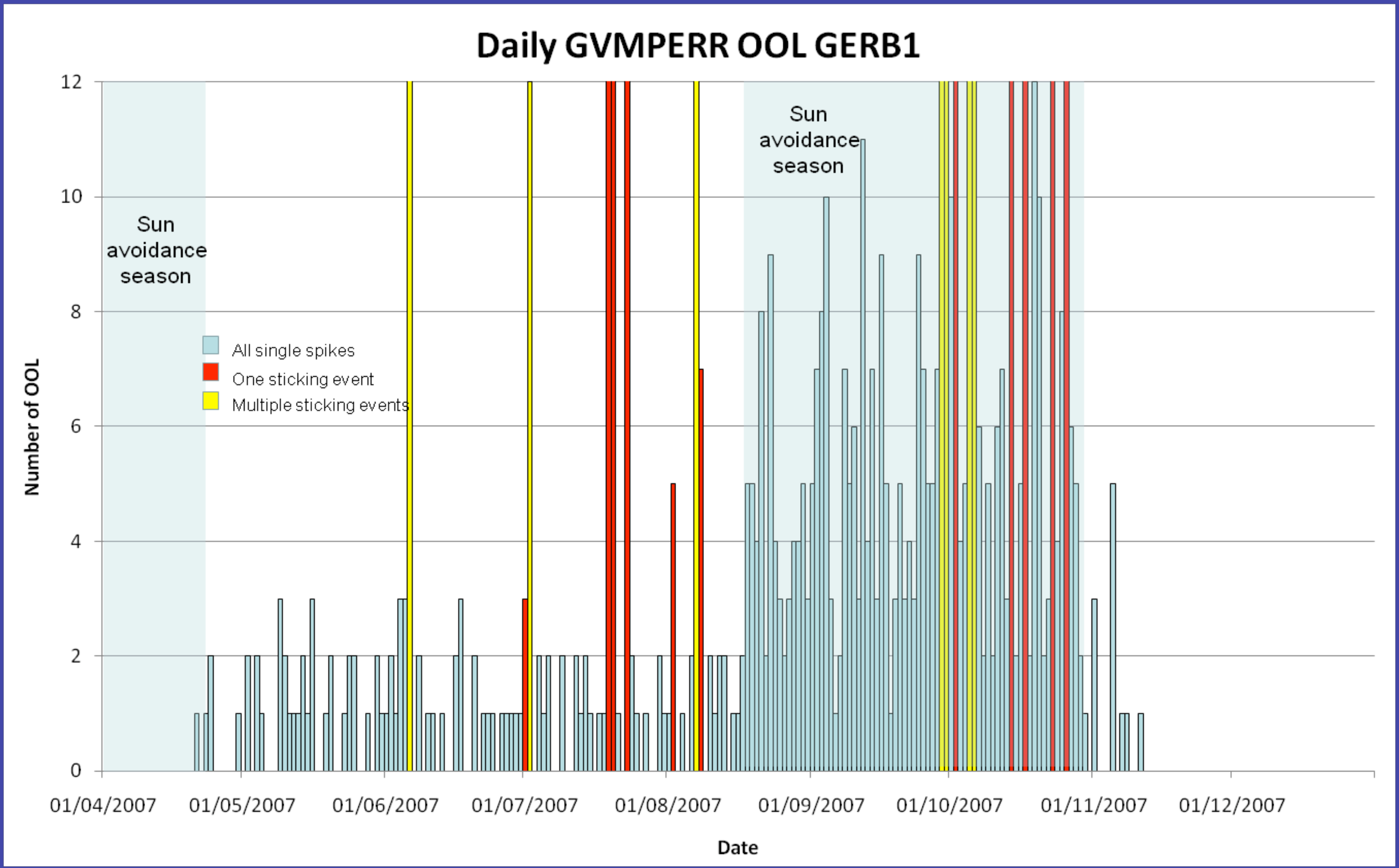
  Detector calibration (flight / flight spare)

  Calibration at Imperial Dec 2008

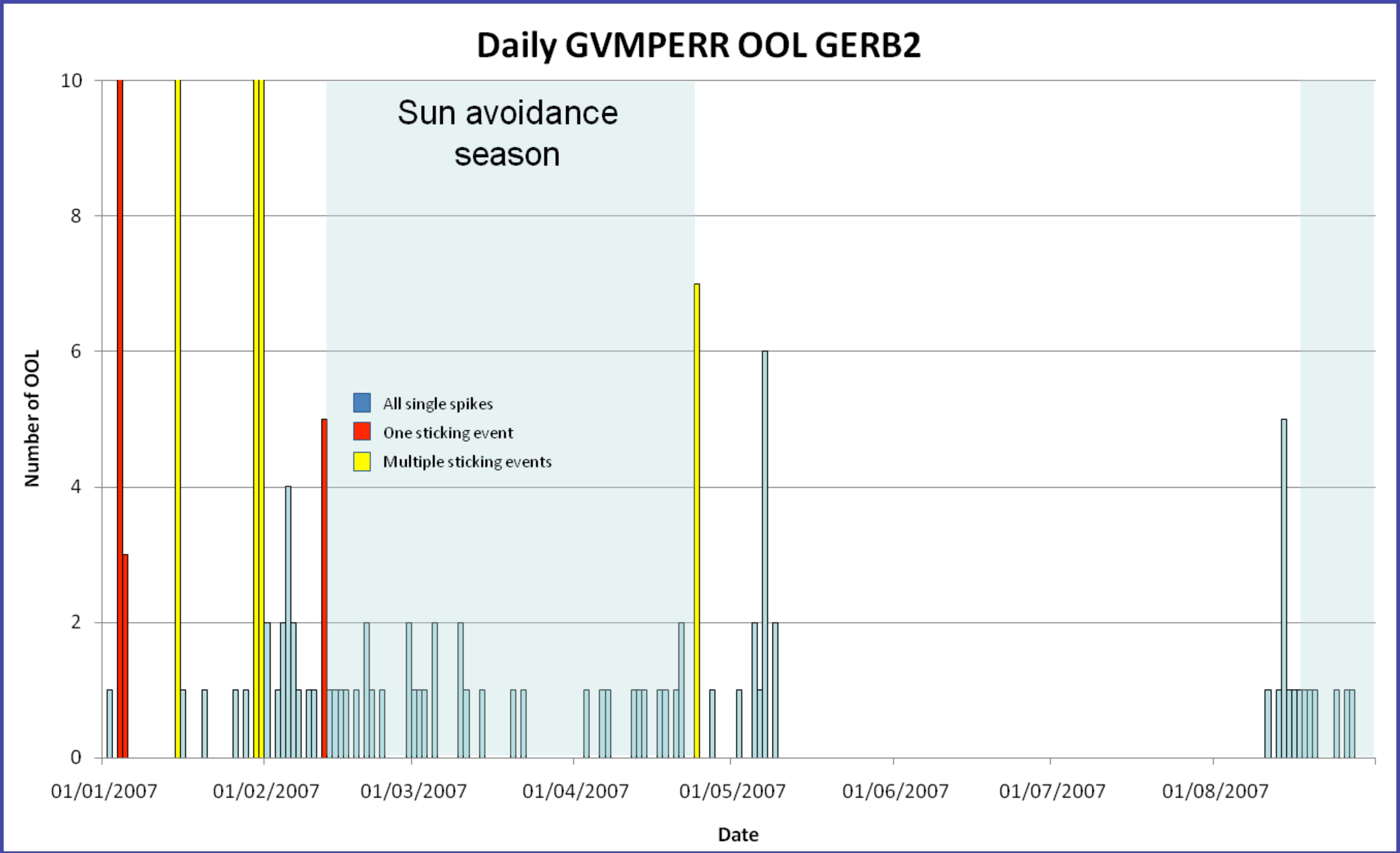
GERB 1 & 2 Performance

- Concerns over GERB-1 mirror bearing performance (sticking / jamming events)
- GERB-1 run in “sun block” during recent SAS
- Equivalent performance of GERB-2 at similar lifetime stage totally different
- GERB-1 mirror performance improvement in “normal” mode

GERB-1 mirror performance

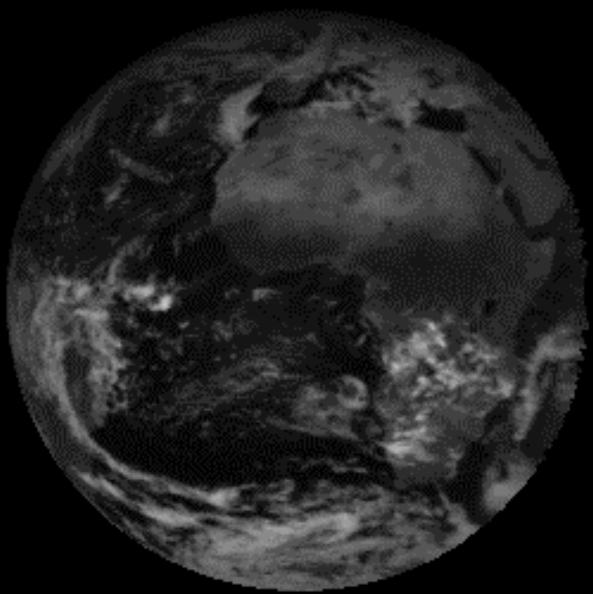


GERB-2 mirror performance

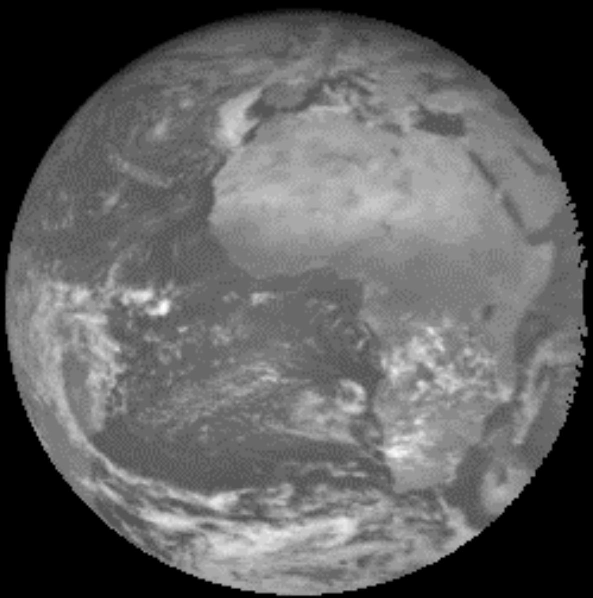


GERB data

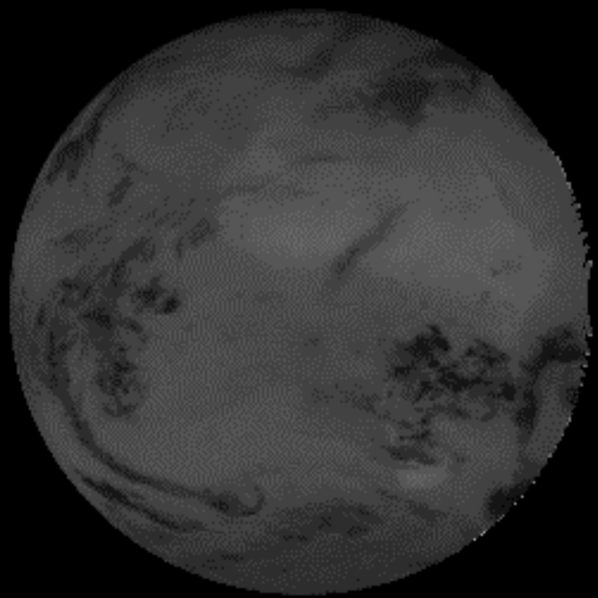
- Nominal GERB region 60N-60S, 60E-60W
- Scanned in shortwave (0.3 to 4μm) and total bands (0.3 to >200μm) in just over $5^1/_2$ minutes
- Flux products for region provided as 3 scan averages (16'42''), or 15 minute averages.
- GERB-2 on geostationary MSG-1 began commissioning beginning 2003 at 10°W. Satellite declared operational Feb 2004, moved to 3.5°W. GERB-2 Edition record from 25/03/2004 – 10/05/2007. GERB-1 0°, Apr 2007.



Shortwave channel



Total channel



Longwave

Edition 1 Products - Availability

Level 1.5 NANRG (Non Averaged Non Rectified Geolocated)

– NRT and climate archive product

Filtered radiances for each GERB pixel observation (TOT and SW)

Level 2 ARG (Averaged Rectified Geolocated)

– NRT and climate archive product

Unfiltered reflected solar and emitted thermal radiances and fluxes, three scan averages interpolated to a regular grid (effect of instrument point spread function not corrected)

Level 2 BARG (Binned Averaged Rectified Geolocated)

– NRT and climate archive product

15 minute averages of unfiltered reflected solar and emitted thermal radiances and fluxes, uniform area averages, i.e. effect of instrument point spread function corrected

Level 2 SHI (Standard High Resolution)

– NRT product only

Unfiltered reflected solar and emitted thermal radiances and fluxes, snapshot at SEVIRI acquisition time, 3x3 SEVIRI pixel resolution

“Holes” in the GERB Edition 1 data record

- Satellite / instrument outage
- Sun avoidance season
  - Extended periods of no data
  - 5 hours of missing data ~8.30pm – 2am
- Sun glint affecting SW fluxes
- Dusk / dawn (terminator)

GERB on MSG-1 data gaps

Start date	End date	Nature of outage
14-Feb-2004	23-Apr-2004	Sun avoidance, GERB switched to SUNBLOCK mode 20:30 - 02:00 nightly
31-Jul-2004	22-Sep-2004	Instrument anomaly and follow-up testing
22-Sep-2004	03-Oct-2004	Sun avoidance, GERB switched to SUNBLOCK mode 20:30 - 02:00 nightly
03-Oct-2004	08-Oct-2004	MSG satellite outage, no data.
08-Oct-2004	29-Oct-2004	Sun avoidance, GERB switched to SUNBLOCK mode 20:30 - 02:00 nightly
14-Feb-2005	01-Mar-2005	Sun avoidance, GERB switched to SUNBLOCK mode 20:30 - 02:00 nightly
01-Mar-2005	23-Apr-2005	GERB off following instrument anomaly
18-Aug-2005	29-Oct-2005	Sun avoidance, GERB switched to SAFE mode for entire period
14-Feb-2006	23-Apr-2006	Sun avoidance, GERB switched to SUNBLOCK mode 20:30 - 02:00 nightly
19-Aug-2006	29-Oct-2006	Sun avoidance, GERB switched to SUNBLOCK mode 20:30 - 02:00 nightly
23-Sep-2006	10-Oct-2006	MSG satellite outage, no data. GERB back on in SUNBLOCK mode from 05-Oct to 10-Oct.
13-Feb-2007	24-Apr-2007	Sun avoidance, GERB switched to SUNBLOCK mode 20:30 - 02:00 nightly
10-May-2007	N/A	Official end of MSG-1/GERB-2 operations, GERB-2 switched to SAFE

Edition 1 record: 25-Mar-2004 to 10-May-2007

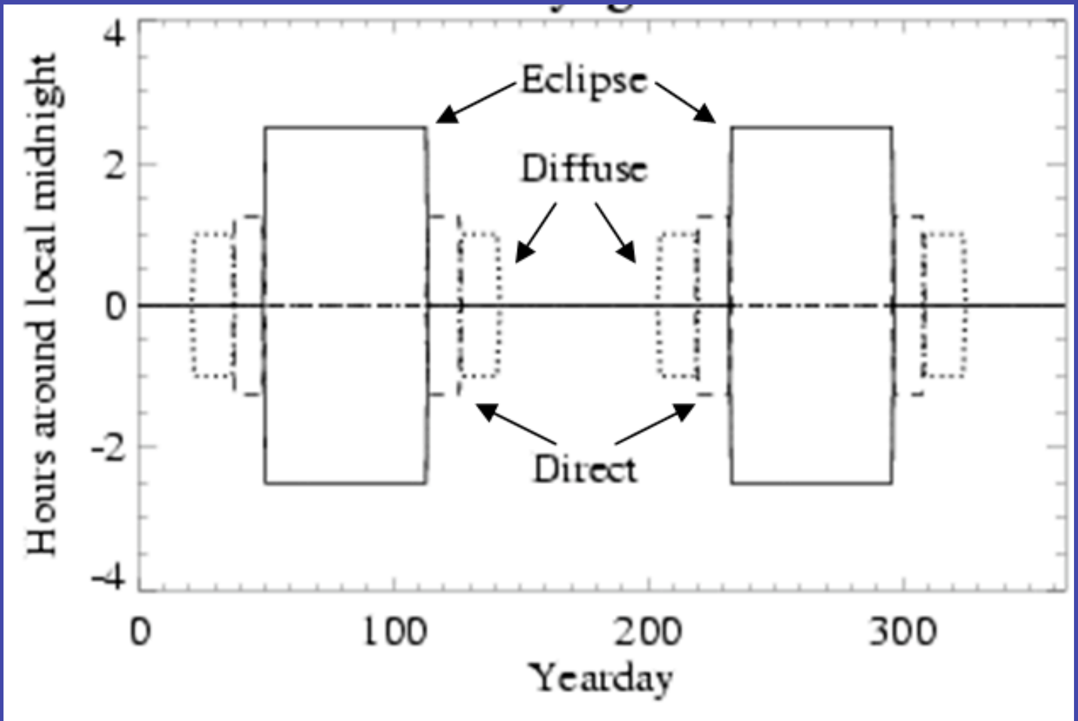
Eclipse operations and stray light

• GERB's wide FOV means that at equinoxes Sun passes behind Earth, and is in GERB FOV around midnight;

• Eclipse (Sun Avoidance Season) affects 10-12 weeks centred on each equinox, no science data from about 20.30 to 02.00

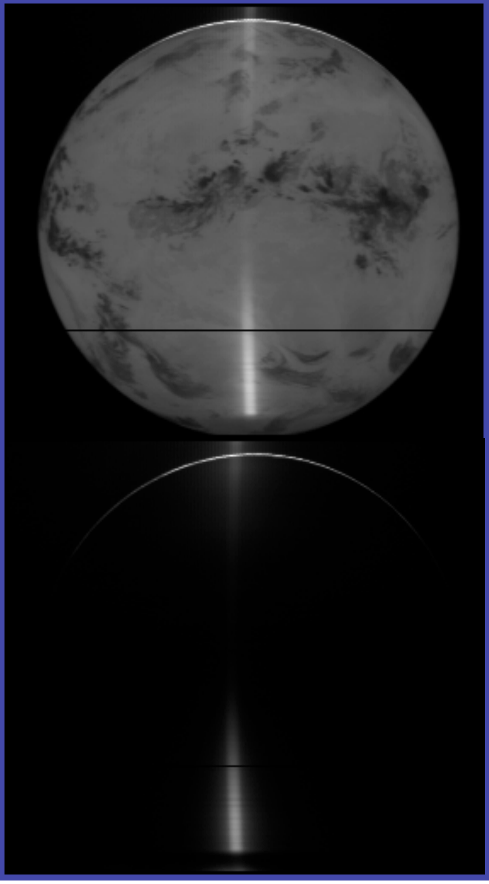
- Possible solution to use scaled GERB-like data

• As Sun approaches, stray light can cause contamination of data

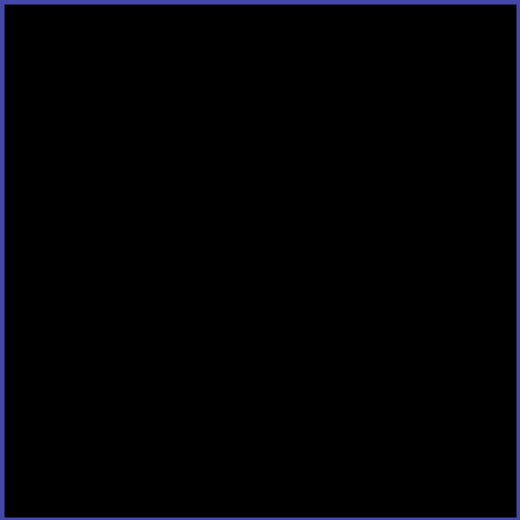


Time of stray-light and eclipse effects

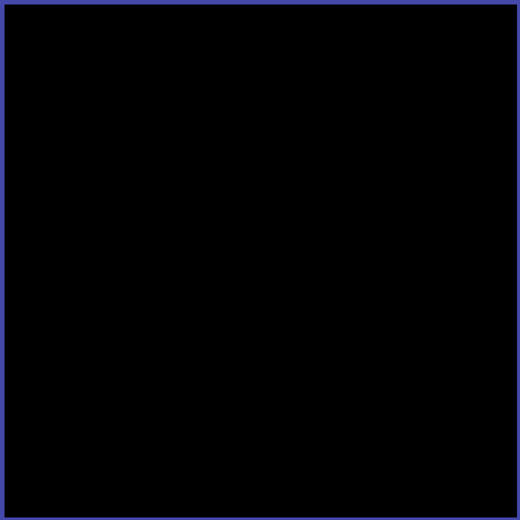
Direct stray light



GERB L2 ARG SW Flux – Sun glint



02 June 2004



01 Jan 2005

- Sun glint
  - Affects SW flux (diurnal cycle, daily / monthly / annual means)
  - possible solutions:
    - [1] Develop IR cloud detection / scene id over ocean
    - [2] Interpolation of albedo / scene id over ocean

NB: Data removed over land unnecessary, but will not be replaced in ARG

Dusk, dawn & terminator

- Affects radiances & fluxes
  - possible solutions:

[1] Linear interpolation to SW=0 at SZA=90, SW=0 for SZA>90

[2] Linear interpolation to 7.5 Wm-2 at SZA=90, CERES dawn/dusk for 90<SZA<105, SW=0 at SZA>105 degrees

[3] Linear interpolation to CERES twilight estimates at SZA=85 (~40 Wm-2) and CERES twilight values thereafter up to SZA=105 (SW=0 for SZA>105).

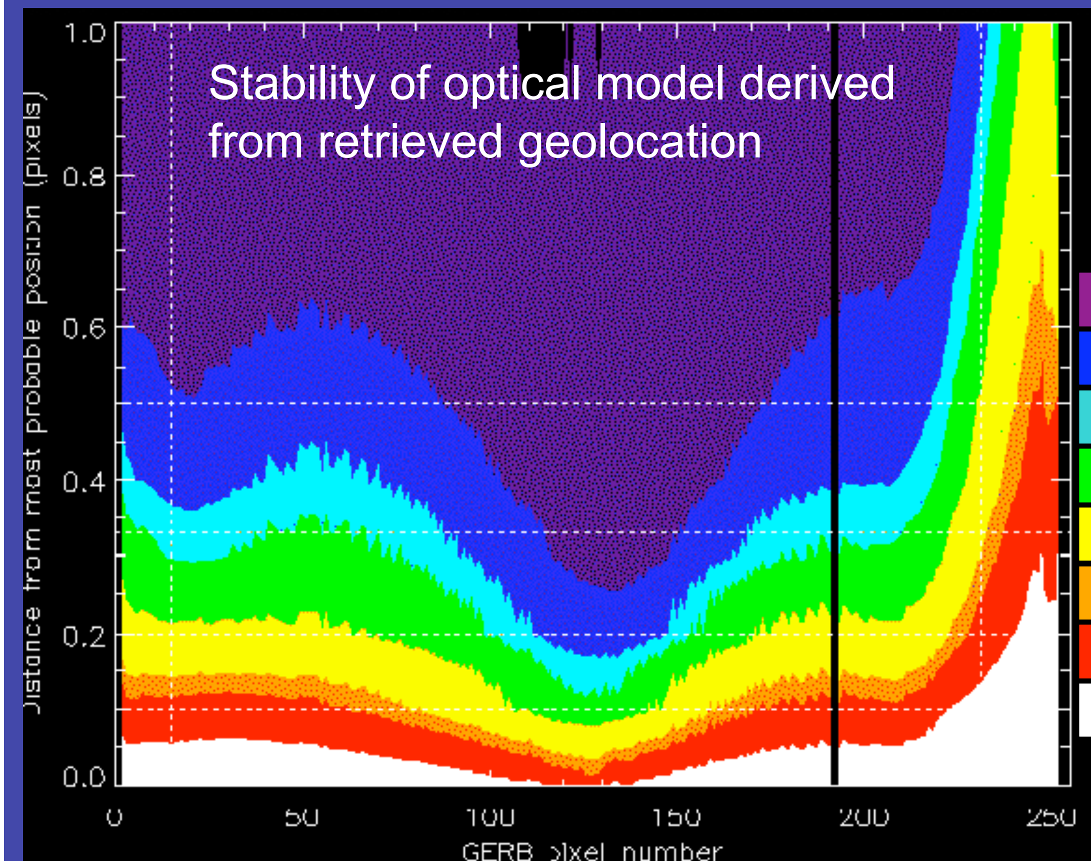
Proposed amendments

- No change to currently released Edition 1 products – L1.5 NANRG & L2 ARG
- Additions to the L2 BARG (unreleased)
  - Recovered sun glint SW fluxes over land
  - SW fluxes included for sun glint over ocean
  - LW data from 5 hour night time period (SAS)
  - Filled dawn, dusk & terminator
  - Inclusion of a “filled” flag

Geolocation

Target accuracy 0.1 GERB pixel: Requires precise knowledge of where in the MSG spin (100rpm) data is acquired.

Accuracy of spin timing information from MSG much poorer than specified, plus delay in obtaining spin structure axis misalignment information from EUMETSAT: interim (ED1) solution is to match GERB to SEVIRI observations.



Performance: most pixels matched to 0.5 pixel; 90% to 0.33 pixel; 75% matched to 0.2 pixel.

1% of cases
4% of cases
5% of cases
15% of cases
25% of cases
10% of cases
20% of cases
20% of cases

Long term (ED2): develop hybrid analytical/empirical model for motion of spacecraft and satellite rotation. Not all aspects of geolocation behaviour currently understood

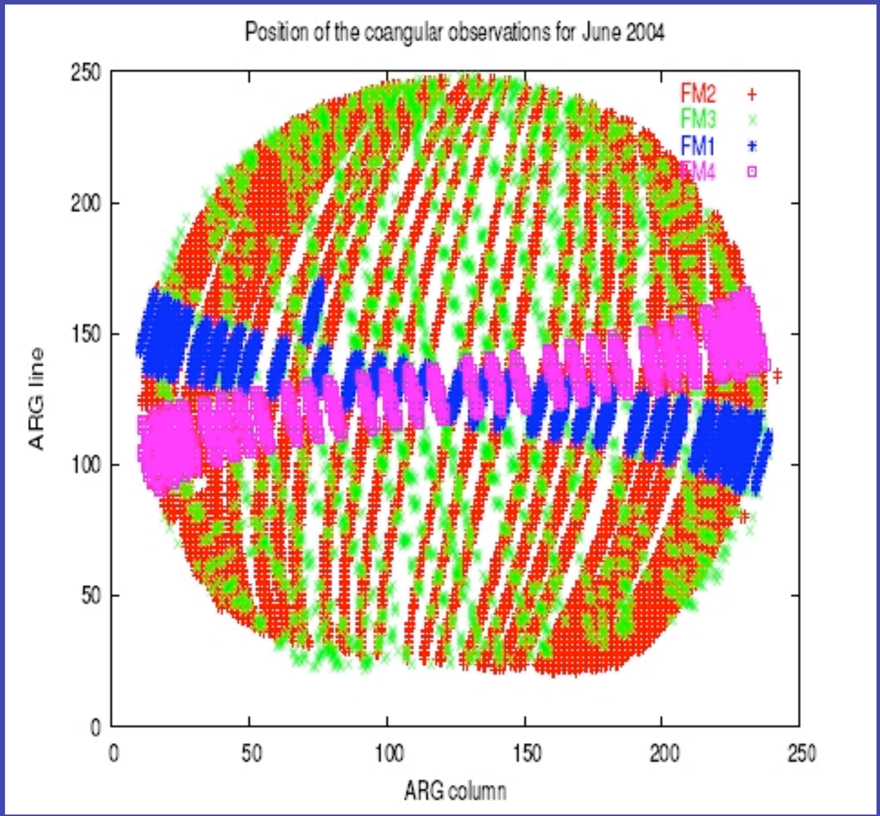
GERB – CERES Comparisons

(N Clerbaux – RMIB)

- GERB Edition 1 ARG (radiance & flux)
- CERES SSF Edition 2 (2B – FM2, 2A – FM3) Rev.1 for SW
- June 2004 & December 2004
- Full detailed study available from: ftp://gerb.oma.be/Documents/ED01_comp.pdf

Radiance Comparisons – methodology

- Co-angular comparisons using the criteria:
  [1] α < 5° [2] Δt ±170s [3] VZA<65° [4] SZA<80°



FM1 & 4 – poor dispersion due to cross-track mode

FM 2 & 3 – good coverage due to RAPS and PAPS modes

$$m_{day} = \frac{< v_{gerb} >}{< v_{ceres} >}$$

GERB / CERES summary

Data for June – 10 July 2004

Data Compared	CERES instrument	FM2 Edition 2B GERB ARG / CERES SSF rev1	FM3 Edition 2A GERB ARG / CERES SSF rev1
SW radiance	All sky	**1.056 ± 0.005** 1.053 ± 0.005	**1.070 ± 0.005** 1.072 ± 0.008
	Overcast	**1.037 ± 0.008** 1.036 ± 0.008	**1.047 ± 0.008** 1.046 ± 0.012
	Clear sky	**1.071 ± 0.006** 1.065 ± 0.006	**1.088 ± 0.005** 1.087 ± 0.007
	Clear ocean	**1.144 ± 0.021** 1.146 ± 0.043	**1.101 ± 0.028** 1.086 ± 0.053
LW radiance	Night	**0.990 ± 0.001** 0.989 ± 0.003	**0.983 ± 0.001** 0.982 ± 0.001
	Day	**0.993 ± 0.001** 0.993 ± 0.001	**0.984 ± 0.001** 0.982 ± 0.003
SW flux	All sky	**1.070 ± 0.002** 1.066 ± 0.006	**1.081 ± 0.003** 1.082 ± 0.004
	Overcast	**1.056 ± 0.005** 1.049 ± 0.006	**1.066 ± 0.003** 1.067 ± 0.005
	Clear sky	**1.070 ± 0.002** 1.074 ± 0.004	**1.092 ± 0.002** 1.093 ± 0.007
	Clear ocean	**1.093 ± 0.010** 1.085 ± 0.018	**1.079 ± 0.008** 1.072 ± 0.014
LW flux	Night	**0.987 ± 0.001** 0.987 ± 0.001	**0.982 ± 0.001** 0.982 ± 0.001
	Day	**0.991 ± 0.001** 0.991 ± 0.001	**0.986 ± 0.001** 0.985 ± 0.001

Flux comparisons - methodolgy

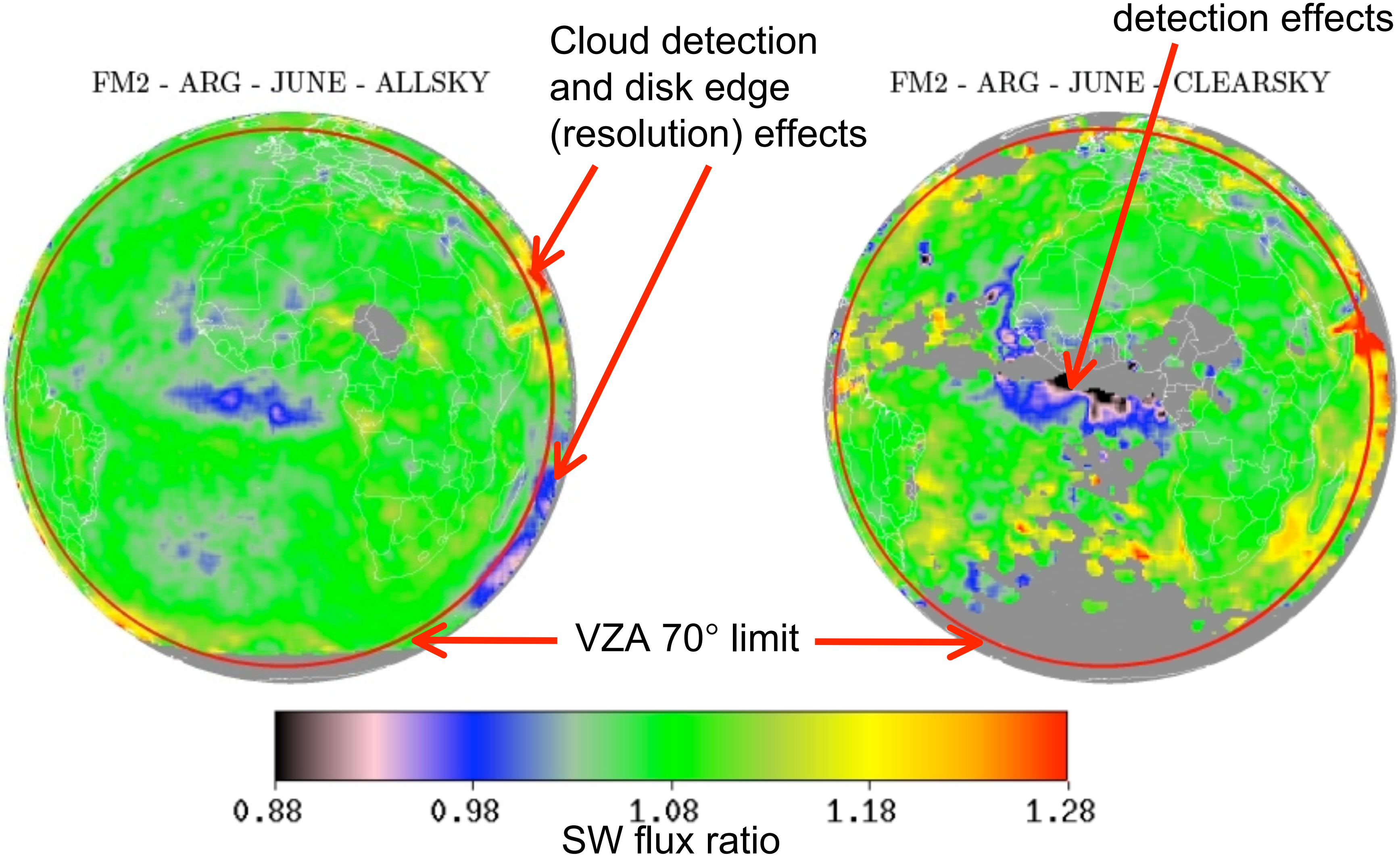
- Co-located comparisons using the criteria:
  [1] $\Delta t \pm 170s$

  <u>SW flux</u>
  [2] VZA < 65°
  [3] SZA < 80°

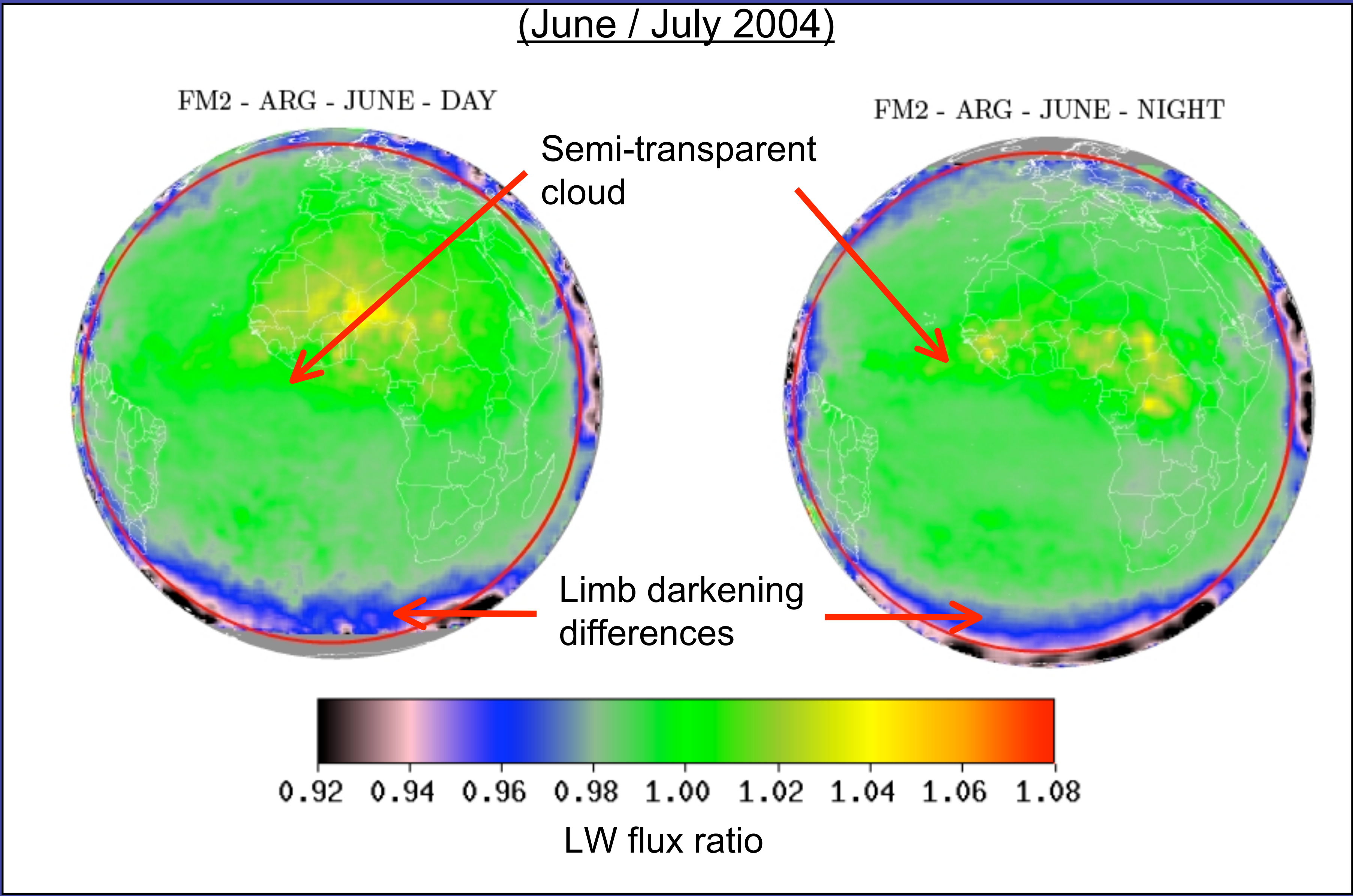
  <u>LW flux</u>
  [2] VZA < 70° & SZA < 80° (day time)
  [2] SZA > 100° (night time)

SW flux comparison

(June / July 2004)



LW flux comparison



Future comparison studies exploiting overlap data between GERB 1 & 2

Dates	GERB-1 (MSG-2) longitude (˚E)	GERB-2 (MSG-1) longitude (˚E)	CERES PAPS scan time and location
24/04/06 –04/07/06	-6.65 to -6.35	-3.55 to -3.25	01/06/06 – 30/06/06 6.5 W (S Hemi)
19/07/06 – 17/08/06	+0.5 to +0.25	-3.55 to -3.45	N/A
09/01/07 – 10/02/07	+0.0 to +0.8	-3.6 to -3.45	19/01/07 – 10/02/07 1.75 W (N Hemi)
19/04/07 – 10/05/07	-0.4	-3.55	N/A

- GERB 1 & 2 filtered radiance and flux data
- GERB 1 & 2 unfiltered radiance with co-angular CERES (PAPS)
- GERB 1 & 2 fluxes with CERES for a range of viewing geometries
- GERB 1 & 2 with surface data from Valencia Anchor Station and CERES PAPS located over region

Processing improvements in the pipeline for GERB Edition 2 release

- Geolocation: method (by matching) not ideal solution and can't meet spec for some products – improvement and further information on spacecraft behaviour still required
- Spectral response: Ongoing analysis of the GERB-CERES differences, including further measurements on flight spare detector to provide further input to detector spectral response and pixel-to-pixel variability
- LW and SW radiance to flux conversion: Improving accuracy of fluxes is an ongoing research activity, specialised treatment of SW fluxes in the presence of aerosol and LW fluxes for thin cloud being developed. Clear sky diurnal asymmetry problem being improved.

27th GERB International Science Team Meeting (GIST)

- 16th – 18th January 2008
- University of Valencia, Valencia, Spain
- Email: gerb@imperial.ac.uk

Additional Slides

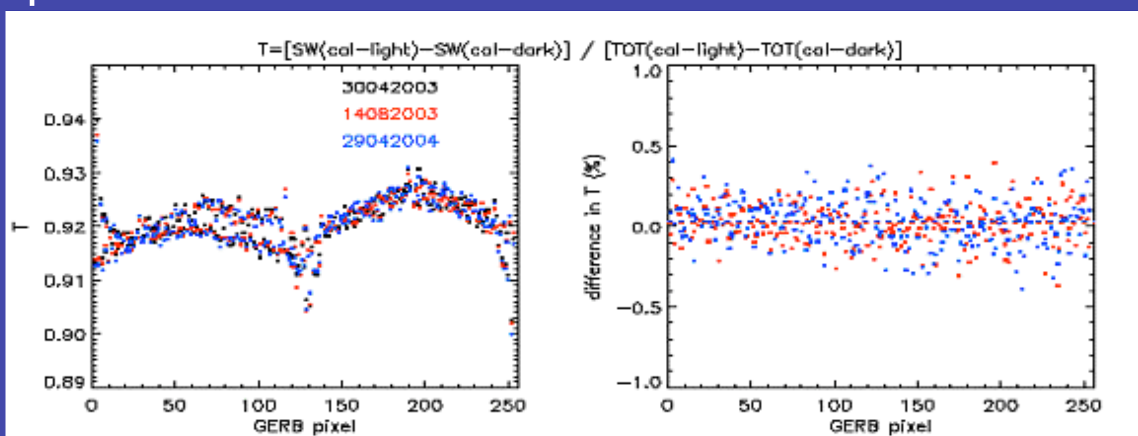
Instrument stability, noise and filter transmission monitoring

Gain calculated every 5 minutes on a rolling basis, found to be stable over several days (avoid occasional errors due to moon, stray solar);

Deep space and internal black body views used to evaluate instrument noise
For 3-scan (15 min) average, pixel noise:

< ±0.3 $Wm^{-2}sr^{-1}$ for SW (pre-launch spec: 0.8 $Wm^{-2}sr^{-1}$),
< ±0.4 $Wm^{-2}sr^{-1}$ for LW (pre-launch spec: 0.19 $Wm^{-2}sr^{-1}$)

Filter transmission (for SW channel) monitored using on-board integrating sphere. Transmission stable to within 0.1%



$$T(CALMON) = \frac{\left\{\left[\overline{V_{sw}(CALlight) - V_{sw}(ibb)}\right] - \left[\overline{V_{sw}(CALdark) - V_{sw}(ibb)}\right]\right\}}{\left\{\left[\overline{V_{tot}(CALlight) - V_{tot}(ibb)}\right] - \left[\overline{V_{tot}(CALdark) - V_{tot}(ibb)}\right]\right\}}$$

Shortwave Radiance

SCENE TYPE	FM1	FM2	FM3	FM4
ALL TOGETHER				
JUNE	1.046 ± 0.007	1.056 ± 0.005	1.070 ± 0.005	1.071 ± 0.007
DEC.	1.046 ± 0.008	1.051 ± 0.004	1.069 ± 0.004	1.071 ± 0.008
OVERCAST $CC = 100\%$ and $ln(\tau) > 2$				
JUNE	1.012 ± 0.014	1.037 ± 0.008	1.047 ± 0.008	1.034 ± 0.018
DEC.	1.018 ± 0.012	1.031 ± 0.007	1.055 ± 0.009	1.052 ± 0.030
CLEARSKY $CC = 0\%$				
JUNE	1.076 ± 0.009	1.071 ± 0.006	1.088 ± 0.005	1.090 ± 0.017
DEC.	1.088 ± 0.068	1.061 ± 0.004	1.086 ± 0.006	1.094 ± 0.013

$$m_{day} = \frac{< v_{gerb} >}{< v_{ceres} >}$$

Longwave Radiance

	FM1	FM2	FM3	FM4
JUNE DAY	0.994 ± 0.001	0.993 ± 0.001	0.984 ± 0.001	0.981 ± 0.001
JUNE NIGHT	0.983 ± 0.002	0.990 ± 0.001	0.983 ± 0.001	0.983 ± 0.001
JUNE D & N	0.989 ± 0.001	0.992 ± 0.001	0.984 ± 0.001	0.982 ± 0.001
DEC. DAY	0.995 ± 0.002	0.993 ± 0.001	0.981 ± 0.001	0.978 ± 0.002
DEC. NIGHT	0.982 ± 0.002	0.988 ± 0.002	0.981 ± 0.001	0.980 ± 0.003
DEC. D & N	0.988 ± 0.002	0.992 ± 0.001	0.981 ± 0.001	0.979 ± 0.001
ALL TOGETHER	0.988 ± 0.001	0.992 ± 0.001	0.982 ± 0.001	0.980 ± 0.001

Table 2: LONGWAVE RADIANCE INTERCOMPARISON

Absolute accuracy of radiances

Error source	Reflected solar	Emitted thermal (night)	Emitted thermal (day)
Calibration sources absolute accuracy (1 SD uncertainty values)	~0.22%[3]	<0.05%[4]	
Calibration sources uniformity (full range over region used)	< 0.5%	Small	
Spectral response [5]	1.9% of typical full scale	<0.9% of typical full scale	<0.9% of typical full scale
Stray light (maximum effect in unflagged data)	$<0.25\ Wm^{-2}sr^{-1}$ [6]		
	<0.1% of typical full scale	<0.3% of typical full scale	
Polarisation	<0.4%[7]	Small	
SEVIRI inter-channel calibration[8]	<1%	<0.1%	<0.1%
RMS combination of above errors	**2.25%**	**0.96%**	**0.96%**

Table 2. Estimates of the ground determined unfiltered radiance bias error sources and magnitudes.

Random uncertainties on radiances

Error source	Reflected solar	Emitted thermal (night)	Emitted thermal (day)
Instrument noise	0.13% of typical full scale	0.4% of typical full scale	0.6% of typical full scale
Geolocation[9]	0.25 pixel		
Interpolation[10]	0.63% of typical full scale	1% of typical full scale	1% of typical full scale
Spectral overlap correction	0.02% of typical full scale	None	0.08%
Unfiltering	0.3% of typical full scale	0.05% of typical full scale	0.05% of typical full scale

Table 3. Estimates of the random errors on the unfiltered radiance.

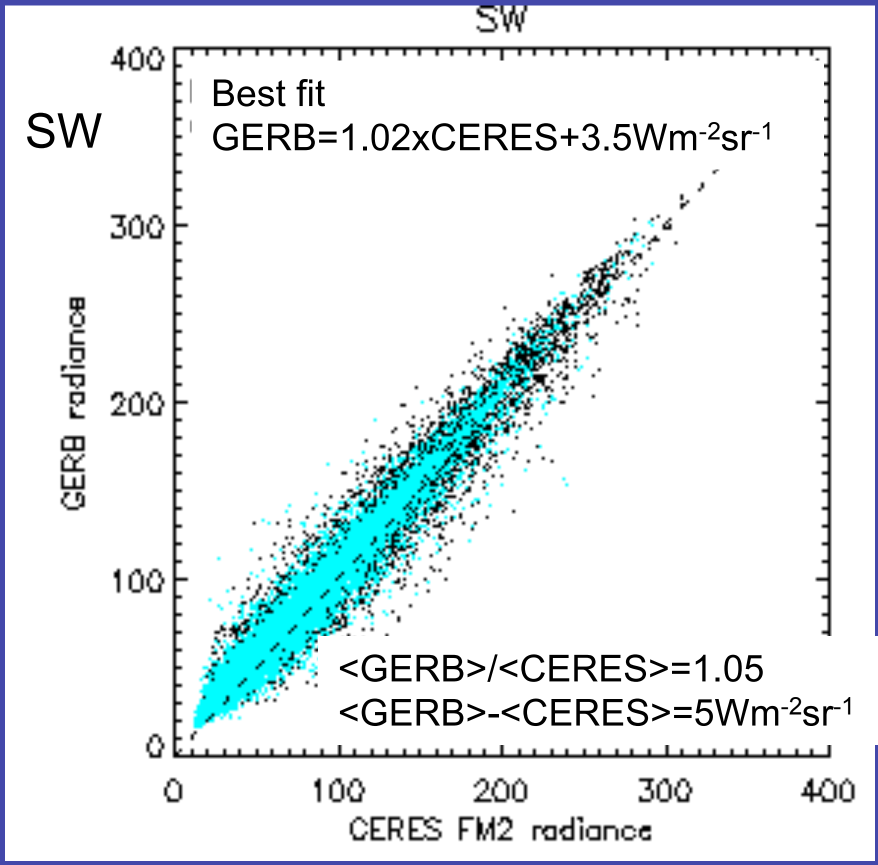
Additional uncertainties on Flux

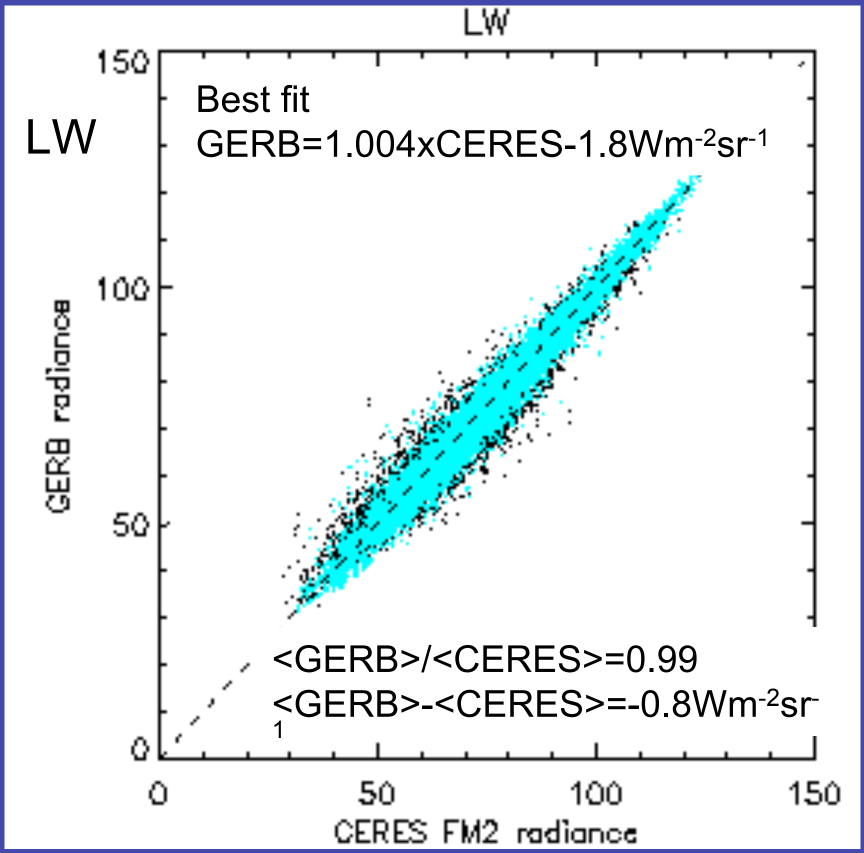
Error source	Reflected solar	Emitted thermal
SW ADM	~10 $Wm^{-2}sr^{-1}$ random error	
LW anisotropy		2.3% random error (of typical full scale)
SEVIRI channel calibration and inter-channel calibration[11]	< 0.5% bias < 2.3% random error (of typical full scale)	< 1.3% bias (of typical full scale)

Table 4. Addition error sources and approximate magnitudes to which the SW and LW fluxes are subject (see Loeb et al. 2003 for validation results on the CERES TRMM ADMs).

Inter-comparison of GERB and CERES radiances

Valuable collaboration between GERB and CERES, and thanks to CERES team for helping GERB project;
Special scanning pattern enables CERES to view same surface pixel *along same line of sight*;
Particularly important for highly anisotropic SW radiances



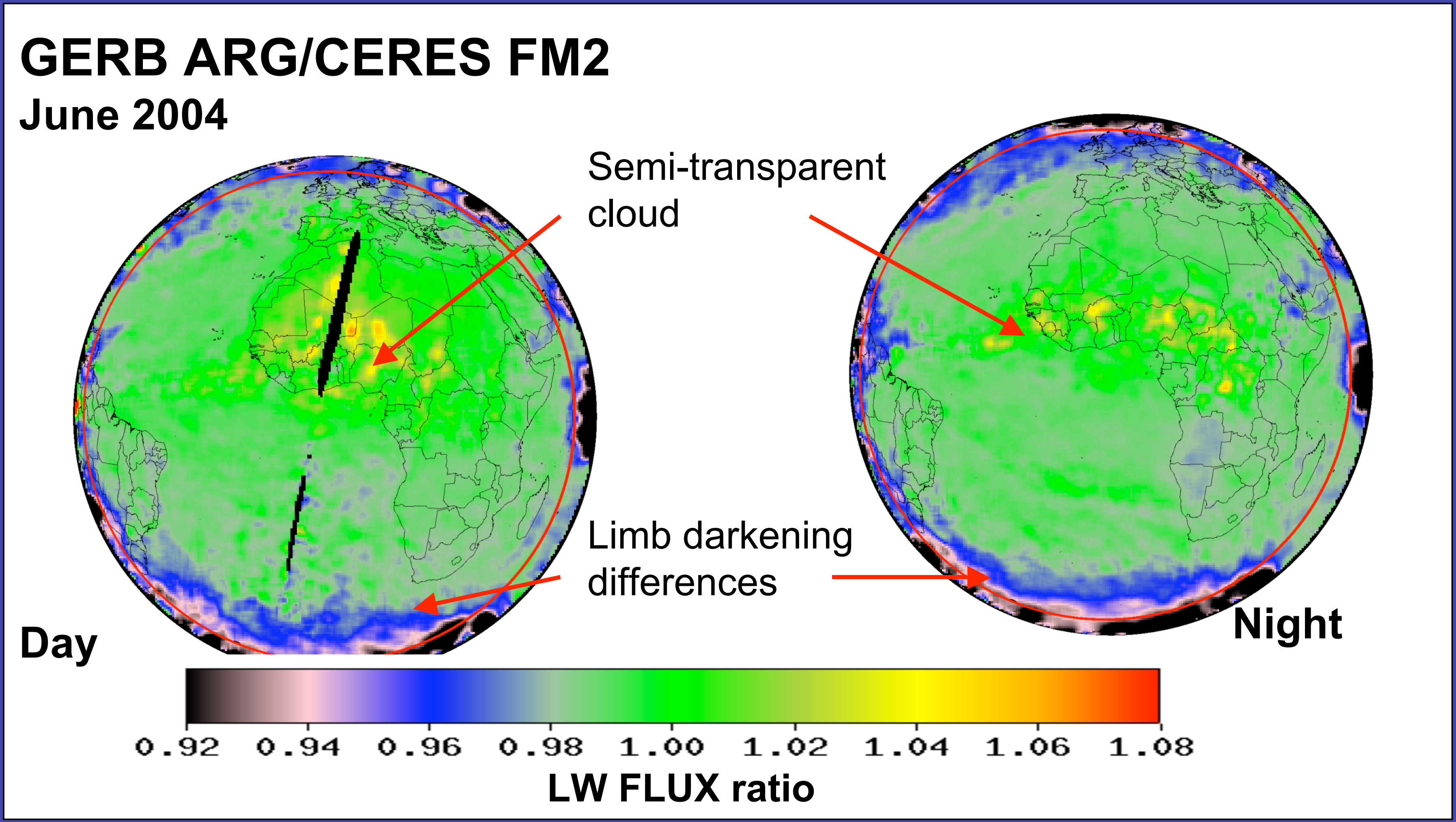


Radiance comparison results

SW radiance data	FM2 (Edition 2) GERB/CERES	FM3 (Edition 1b)
All points June Dec	1.058 ± 0.005 1.048 ± 0.005	1.067 ± 0.013 1.075 ± 0.006
Overcast June Dec Cloud cover = 100% τ>7.4	1.041 ± 0.013 1.032 ± 0.005	1.039 ± 0.016 1.050 ± 0.017
For Clear GERB pixels (GERB cloud cover 0%)		
Ocean	1.144 ± 0.043	1.084 ± 0.052
Dark Vegetation	1.070 ± 0.017	1.089 ± 0.039
Bright Vegetation	1.062 ± 0.010	1.086 ± 0.013
Dark Desert	1.073 ± 0.019	1.101 ± 0.035
Bright Desert	1.059 ± 0.006	1.082 ± 0.012

LW radiance data	FM2 GERB/CERES	FM3
All daytime points June Dec	0.993 ± 0.001 0.993 ± 0.001	0.985 ± 0.003 0.979 ± 0.002
All night time points June Dec	0.990 ± 0.003 0.988 ± 0.005	0.982 ± 0.002 0.981 ± 0.002

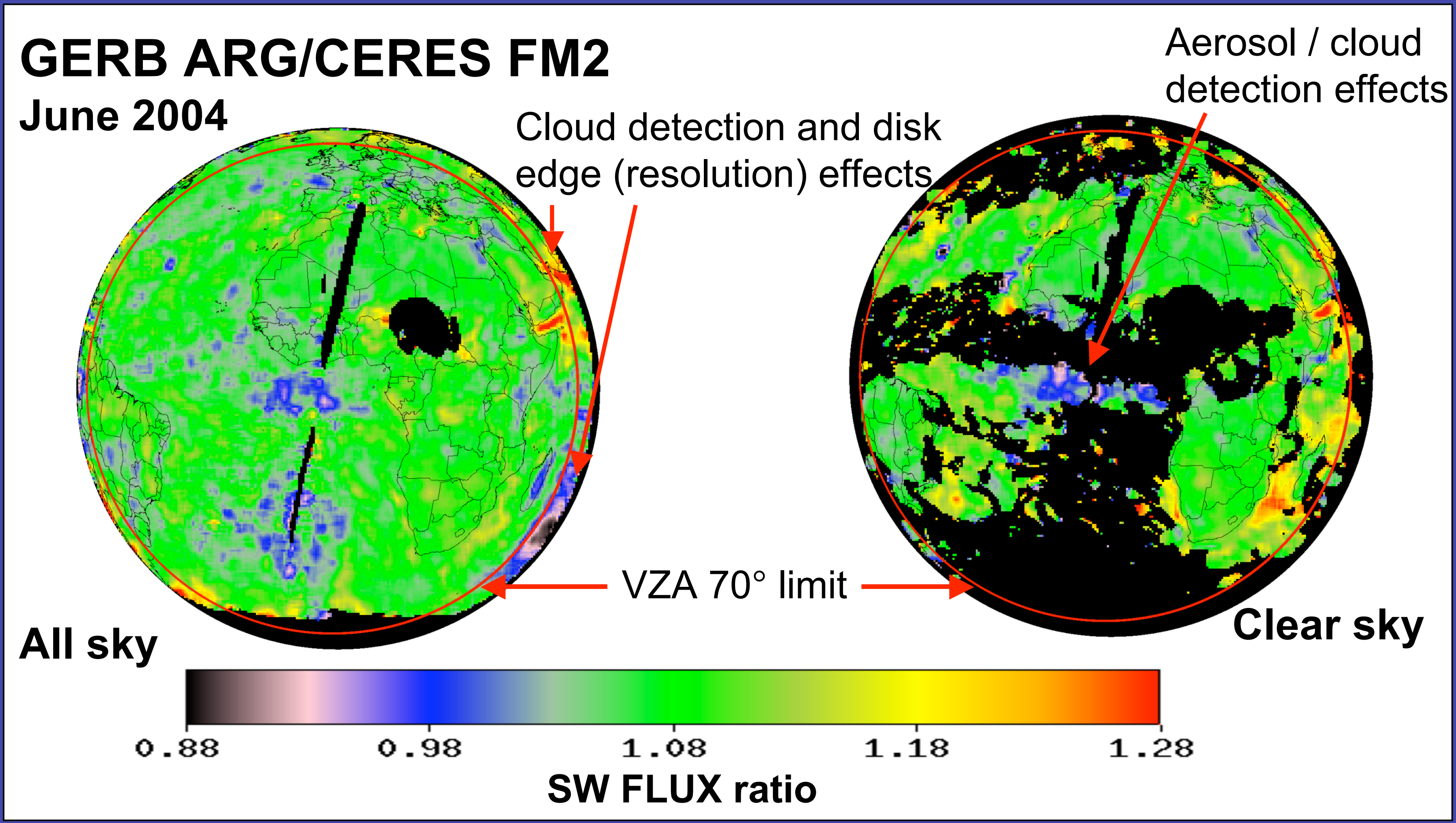
LW Flux comparison



Know problems exist with the LW anisotropy factors for semitransparent cloud
Differences seen in the limb darkening of the CERES and GERB fluxes

Average GERB/CERES SW flux ratio 0.99

SW Flux comparison

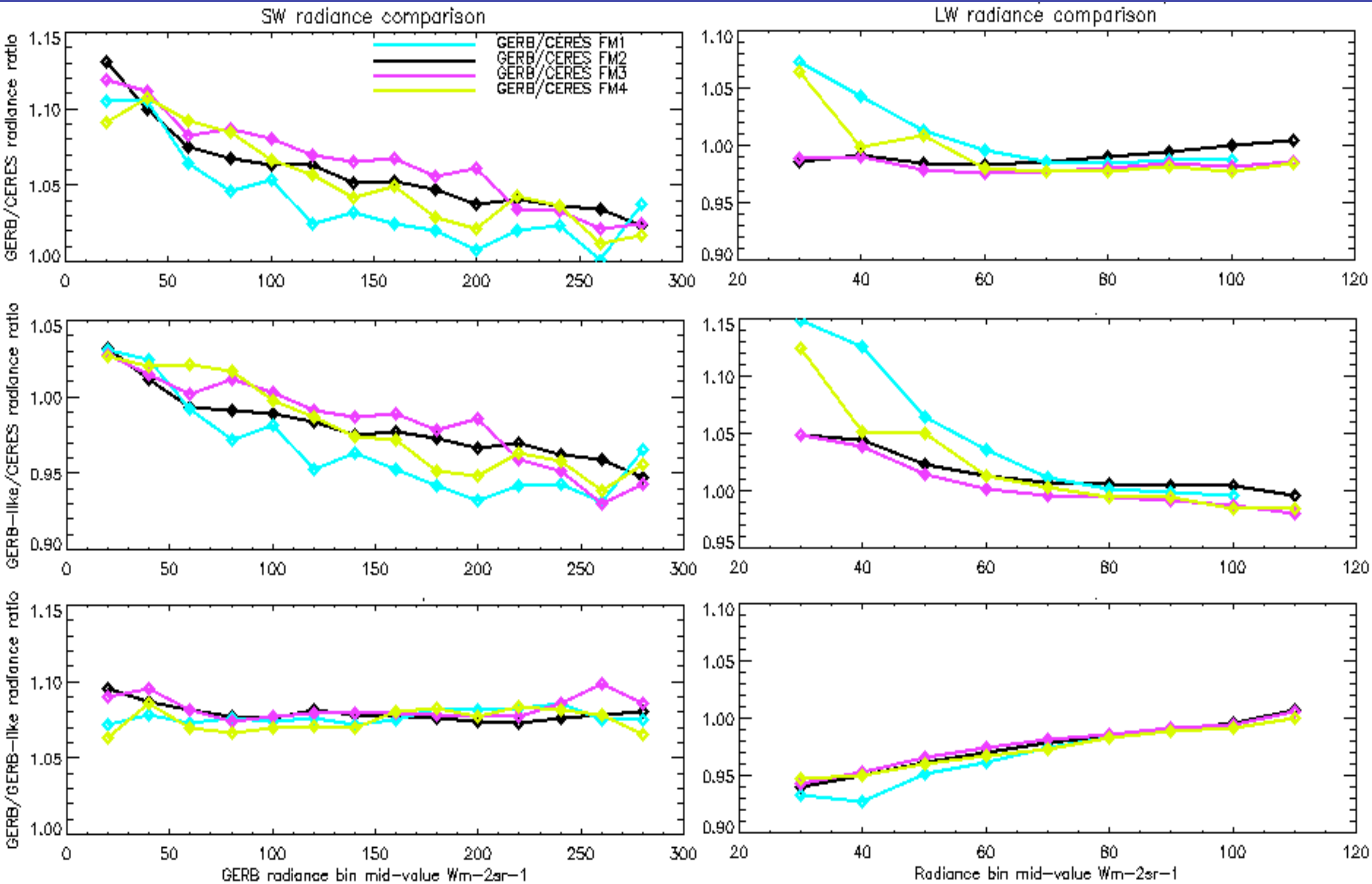


Anisotropy factors are found to be 1% higher than CERES for same scene

Average GERB/CERES SW flux ratio 1.07

DATA used 21-27th June 2004 GERB V998 and CERES FM2 ED2 rev 1 (all-sky)

Radiance comparison: scene dependency



GERB-2 equivalent lifetime